

# Maximum drawdown, recovery, and momentum

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## Abstract

We develop momentum and contrarian strategies with stock selection rules based on maximum drawdown and consecutive recovery. The alternative strategies in monthly and weekly scales outperform the portfolios constructed by cumulative return regardless of market universe. In monthly periods, the ranking rules associated with the maximum drawdown dominate other momentum strategies. The recovery related selection rules are the best ranking criteria for the weekly contrarian portfolio construction. The alternative portfolios are less riskier in many reward-risk measures such as Sharpe ratio, VaR, CVaR, and maximum drawdown. The outperformance of the alternative strategies leads to the higher factor-neutral alphas in the Fama-French three-factor model.

*Keywords:* momentum strategy, maximum drawdown, alternative stock selection rule

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## 1. Introduction

Seeking statistical arbitrage in financial markets is the most important task to academics and practitioners in finance. The chances of the systematic arbitrage are not only the counter-examples to the efficient market hypothesis [1, 2] but also the sources of profitable trading strategies to the practitioners. Among various market inefficiencies, price momentum [3] is a well-known market anomaly that is not explained by the Fama-French three-factor model [4, 5]. Although the price momentum is found in many asset classes and markets [6, 7, 8, 9, 10, 11], it is still inexplicable with numerous ideas such as autocorrelation and cross-sectional correlation [12, 13], sector momentum [14], dissemination of news and behavioral aspects of investors to the news [15, 16, 17, 18], and transaction cost [19].

Introducing various ranking rules to momentum-style portfolio construction is a worthwhile approach to understanding the price momentum. First of all, it is a direct way of searching for potential factors explaining the price evolution.

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Several selection rules have been proposed including time series model [10], trading volume [20], liquidity [21, 22, 23, 24, 25], physical momentum [26], reward-risk measures [27, 28], and 52-week high price [29, 30]. Additionally, new alternative criteria are potential indicators for trading signals.

In particular, the 52-week high momentum strategy [29, 30] is well-matched to the philosophy of the price momentum. Since the 52-week high price is the highest price during the last 52 weeks, the larger return to the highest price in recent one year exhibits the stronger price momentum during the period. Exceeding the 52-week high price is also considered a signal that the asset price has the capability of moving upward in the future. By the similar reasoning, consideration on the 52-week low price is also possible. Unfortunately, the opposite direction is not a successful ranking criterion for the momentum strategy.

The 52-week low price is not the only approach to incorporating the risk into the process of the momentum-style portfolio construction. Rachev et al. [27] paid attention to reward-risk measures such as Sharpe ratio, STARR, and R-ratio. Their alternative portfolios are less riskier with the thinner tails in the S&P 500 universe. As an extension of the study by Rachev et al. [27], the reward-risk momentum strategies using classical tempered stable distribution are implemented in various asset classes and it is found that the alternative strategies exhibit the better performance and risk profile regardless of asset class and market [28].

One of the most popular risk measures is maximum drawdown. It is defined as the worst cumulative decline from a peak in a given period. The maximum drawdown is also used in the definitions of the Calmar ratio and Sterling ratio in order to assess the performance and risk of mutual funds and hedge funds. Several advantages of the maximum drawdown over VaR and CVaR are followings. First of all, it is more insightful than other risk measures. When two historical price charts are given, it is more straightforward to find which asset has the smaller maximum drawdown. Additionally, it is easier to calculate the drawdown directly from time series. Moreover, there is no model dependency.

In this paper, we introduce multiple composite ranking criteria stemmed from the maximum drawdown and successive recovery in order to construct alternative momentum/contrarian-style portfolios. The monthly momentum and weekly contrarian strategies based on the alternative stock selection rules are implemented in U.S. and South Korea stock markets. The alternative strategies outperform the traditional cumulative return based strategies in performance and risk. In particular, the drawdown measures provide the better trend-following strategies in monthly scale and the recovery criteria work well with the weekly strategies. The outperformance is also found in the Fama-French three-factor model. The structure of the paper is following. In the next section, the new ranking rules based on the maximum drawdown and sequential recovery are defined. In section 3, datasets and methodology are introduced. The performance and risk profile of the alternative portfolios are found in section 4. The factor analysis is given in section 5. We close the paper with conclusion in section 6.

## 2. Construction of stock selection rules

As mentioned before, the maximum drawdown is the worst successive loss among declines from peaks to troughs during a given period. It is defined by

$$\text{MDD} = \max_{\tau \in (0, T)} \left( \max_{t \in (0, \tau)} (P(t) - P(\tau)) \right)$$

where  $P(t)$  is the log-price at time  $t$ . The expression can be represented in terms of return

$$\text{MDD} = - \min_{\tau \in (0, T)} \left( \min_{t \in (0, \tau)} R(t, \tau) \right)$$

where  $R(t, \tau)$  is the log-return between  $t$  and  $\tau$ . The maximum drawdown is regarded as the worst-case scenario to an investor who starts his/her investment at any moment in that period. It is obvious for the investor to prefer the lower maximum drawdown to the higher one.

The maximum drawdown is closely related to the price momentum. In particular, the maximum drawdown is associated with the direction of the price momentum. In the case of positive momentum, it is a part of mean-reversion process if the size of the maximum drawdown is small. Additionally, if it is large enough, the maximum drawdown is more likely to break the upward trend and generate new downward trend-following stage. Meanwhile, it is one of the largest components for the downside momentum. The larger maximum drawdown would be much preferred for short position.

The successive recovery to the maximum drawdown is defined by

$$R = R(t^*, T)$$

where  $t^*$  is the moment for the end of the maximum drawdown formation. It encodes how much loss from the worst decline is recovered by the short-term reversal. Similar to the maximum drawdown, it is also helpful to understanding the price momentum. When an asset price is on the upward trend, it is regarded as the support to the original trend. Meanwhile, in downside momentum, the recovery is a reversal to the overall trend. It is obvious that an asset with stronger recovery is favored than an asset with weaker recovery.

In these spirits, the maximum drawdown and consecutive recovery are indispensable in the processes of analyzing and detecting signals for price trend. It is obvious that these measures should be incorporated into the momentum analysis and momentum ranking criteria considered these measures need to be considered in portfolio construction. It is possible to construct new composite selection rules stemming from the maximum drawdown and recovery. For example, even when two assets have the same cumulative return, one with the larger maximum drawdown can be penalized in the ranking measure. In other case, assets with stronger short-term mean-reversion to the maximum drawdowns can be preferred in the alternative ranking system.

Before developing alternative selection rules, we need to take a closer look on the cumulative return. A given estimation period is chronologically decomposed

into three periods. The first period is the peak formulation phase from the beginning of the estimation period to the peak before the downfall. The next stage is the period for the creation of the maximum drawdown. The last stage is the recovery period from the trough associated with the maximum drawdown to the end of the estimation period. The above decomposition on the cumulative return  $C$  is represented with the returns in the three different phases:

$$\begin{aligned} C &= R_I + R_{II} + R_{III} \\ &= PP - MDD + R \end{aligned}$$

where  $PP$  is the log-return during the pre-peak period.

With the decomposition, it is possible to construct hybrid indicators using the maximum drawdown and recovery. Taking weighted average with more weights on certain specific period is one way of the construction. Many possible combinations with the maximum drawdown and consecutive recovery are given in Table 1.

Table 1: Description on alternative selection rules using maximum drawdown and recovery

Portfolio name	Criterion	Description	Weights
C	Cumulative return	traditional momentum/contrarian strategy	(1,1,1)
M	MDD	maximum drawdown	(0,1,0)
R	Recovery	recovery	(0,0,1)
RM	Recovery-MDD	difference between MDD and recovery	(0,1,1)
CM	Cumulative return-MDD	more weights on MDD period	(1,2,1)
CR	Cumulative return+Recovery	more weights on recovery period	(1,1,2)
CMR	Cumulative return-MDD+Recovery	more weights on MDD and recovery periods	(1,2,2)

The C strategy is the benchmark strategy. It is the traditional momentum/contrarian strategy that employs the cumulative return as the ranking criterion. The M and R portfolios are constructed by using the maximum drawdown and recovery as the ranking rule, respectively. More complicated selection rules are stemmed from weighted averages on certain periods. The RM strategy utilizes the difference between the recovery and maximum drawdown. It encodes how much losses are recovered by the short-term reversion. The CM strategy not only considers the cumulative return and but also pays attention to the period of the maximum drawdown. It is a penalty to the assets with the large drawdowns. In the similar way, it is possible to assign the weights on only the recovery period or both of the maximum drawdown and recovery for the CR and CMR strategies, respectively.

### 3. Dataset and methodology

#### 3.1. Dataset

The datasets for this study consist of the KOSPI 200 universe, SPDR U.S. sector ETFs, and S&P 500 universe.

### *3.1.1. South Korea equity market: KOSPI 200*

The KOSPI 200 is a stock benchmark index that is the value-weighted and sector-diversified index with 200 stocks in South Korea stock markets. Historical price information and component-roster are downloaded from Korea Exchange. The period from January 2003 to December 2012 is considered.

### *3.1.2. U. S. equity market: SPDR sector ETFs*

Sector ETFs are selected for simulating sector momentum with the alternative stock selection rules. In particular, the SPDR U.S. sector ETFs are chosen because it is the collection of ETF products for which the equal length of price history is available. The time span covers from January 1999 to December 2012. The SPDR U.S. sector ETFs consist of XLB (Materials), XLE (Energy), XLF (Financial), XLI (Industrial), XLK (Technology), XLP (Consumer Staples), XLU (Utilities), XLV (Health Care), and XLY (Consumer Discretionary).

### *3.1.3. U. S. equity market: S&P 500*

The price information and roster of the S&P 500 historical components are collected from the Bloomberg. The covered time horizon is from January 1999 to December 2012.

## *3.2. Methodology*

The basic methodology for portfolios construction is the momentum-style (or contrarian) portfolios given in Jegadeesh and Titman [3]. Based on given selection rules during 6 months (weeks) of estimation period, assets in market universes are sorted in ascending order. In this study, most criteria will be used in increasing order except for the maximum drawdown. Then several ranking baskets are formulated. In the cases of the S&P 500 and KOSPI 200 universes, numbers of groups are 10 and three baskets are formed for U.S. sector ETFs. The group 1 is for losers that exhibit the worst ranking scores and the last group is for the best performers in the selection rules. Each group is constructed as an equal-weighted portfolio. The winner group is at long (short) position and the loser group is at short (long) position. After 6 months (weeks) of the holding period, each basket is liquidated. The portfolio is constructed at the beginning of every month, i.e. it is the overlapping portfolio.

The risk measures for the portfolio performance are calculated from the daily time series of the overlapping portfolio. The risk model for VaR, CVaR, and Sharpe ratio is the ARMA(1,1)-GARCH(1,1) model with classical tempered stable (CTS) innovation. This model is suggested by Kim et al. [31] and the same model is also used for momentum portfolio construction [28]. For more information, consult with Kim et al. [31] and references therein.

## 4. Results

### 4.1. South Korea equity market: KOSPI 200

#### 4.1.1. Weekly results

In Table 2, the recovery related strategies outperform the traditional mean-reversion strategy obtaining weekly 0.073% under the volatility of 2.841%. In particular, the best performer is the recovery portfolio with the weekly returns of 0.146%, two-times larger than the original contrarian strategy, and the excellent performance is achieved under much smaller standard deviation of 1.757%, almost 1.1% lower than the C strategy. The CR and CMR strategies also obtain the better performance under smaller fluctuation. The portfolio returns are weekly 0.086% and 0.078% under the standard deviations of 2.665% and 2.865%. Meanwhile, the maximum drawdown strategies such as the M, CM, and RM strategies underperform the benchmark strategy in the weekly scale.

The outperformance of the R, CR, and CMR strategies are based on the strong reversal of each ranking basket. First of all, the loser groups of every alternative contrarian strategies perform as well as the loser in the mean-reversion portfolio. The performance of the long positions is in the range from 0.241%–0.314% and the return fluctuations are smaller or comparable with the loser basket in the benchmark strategy. In particular, the loser group in the recovery measure exhibits not only the best performance but also the lowest deviation measure among all the loser baskets. Additionally, the winner basket of the R, CR, and CMR portfolios perform poorer than other portfolios including the cumulative return contrarian portfolio.

According to Table 2, the outperformance of the recovery portfolios such as the R and CR portfolios is achieved by taking less risks. The portfolios are less riskier in every risk measures than the other portfolios by the alternative ranking rules including the cumulative return. The R portfolio provides the largest Sharpe ratio and the CR strategy is one of the top 4 in Sharpe ratio. The lowest 95% VaRs and CVaRs are featured by the R and CR portfolios. In particular, the R strategy exhibits 1.149% daily VaR and 1.391% daily CVaR, the smallest risk measures. An interesting caveat is that the CVaR is much decreased than the VaR. This indicates the existence of the much thinner downside tail in the R portfolio performance. The maximum drawdowns of these two portfolios are also lower than all other strategies.

The each ranking basket in the R and CR portfolios is also less riskier than other competitive ranking groups. The winner and loser groups of these two portfolios exhibit lower VaRs and CVaRs. The loser in the recovery criterion achieves the lowest VaR and CVaR with 1.252% and 1.870%, respectively. The Sharpe ratios of the loser groups are the top 2 largest ones among the other alternative and benchmark strategies. The maximum drawdown of the recovery loser is also smaller than the long position in the traditional contrarian portfolio. For winner groups, the tendency is slightly weaker. Although the short baskets are less riskier in 95% VaR and CVaR, the Sharpe ratios and maximum drawdowns are worse than those of the winner and loser in the C criterion.

However, the riskier short position is more attractive for the profitability of the entire portfolio.

#### 4.1.2. Monthly results

In Table 3, it is found that the maximum drawdown criterion and related stock selection rules provide the alternative momentum strategies outperforming the traditional momentum strategy. The best strategy is the momentum portfolio by the composite rule of cumulative return and maximum drawdown. The monthly average return of 1.433% with the volatility of 7.036% is obtained by the CM portfolio while the cumulative return criterion provides the trend-following strategy with the monthly return of 1.331% and the standard deviation of 6.826%. The CMR and RM strategies are the next best performers with the monthly returns of 1.311% and 1.280% and the standard deviations of 6.729% and 6.241%, respectively. The performance of these portfolios are slightly worse but the volatility levels are also lower than that of the momentum strategy. The CR and M strategies also perform well although the strategies underperform the benchmark strategy. Meanwhile, the recovery strategy obtains the worst performance in monthly scale.

The momentum strategies associated with the maximum drawdown exhibit strong momentum in each ranking group basket. The winner basket of the CM strategy achieves monthly 1.701%, the strongest upside momentum among all long positions including the cumulative return winner. Additionally, the return volatility of the position is only 8.062%, almost 10% smaller than that of the momentum winner. The performance of the CMR winner is as good as the benchmark winner and the fluctuation is relatively lower. In addition to that, the loser groups of the M, RM, CM, and CMR strategies underperform the traditional momentum loser. The short basket of the CM strategy, one of the 3 worst performers in the loser groups, underperforms the loser group in the cumulative return. The short baskets in the RM and CMR strategies also show the stronger downside momentum than the loser group of the traditional momentum strategy.

The risk profiles for the momentum portfolios in Table 3 indicate that the portfolios ranked by the maximum drawdown related selection rules are less riskier in many reward-risk measures than the benchmark. For example, most of the alternative momentum strategies exhibit lower 95% VaR and CVaR levels. Even for RM and CMR portfolios, the difference in risk measure is just a few basis points. Additionally, lower maximum drawdown is featured by the alternative portfolios except for the CR portfolio. Moreover, higher Sharpe ratios than the C-strategy are achieved by the CM, CMR, and RM strategies. In overall, choosing these composite ranking criteria related to the maximum drawdown is better at risk management.

Each ranking group in the drawdown strategies exhibits better risk characteristics. Lower 95% VaR, CVaR, and maximum drawdown levels are achieved by the winner groups comparing with the long basket of the momentum portfolios. Additionally, the Sharpe ratios of the long baskets are larger than that

of the momentum winner group. The better reward-risk and smaller risk measures are favorable for the long position. Meanwhile, the loser groups are under greater exposure to the risk with higher 95% VaR, 95% CVaR, and maximum drawdown. The Sharpe ratios for the short baskets are weaker than the momentum loser. For short position, the larger risk of losing money is more desirable.

#### *4.2. U.S. equity market: SPDR sector ETFs*

##### *4.2.1. Weekly results*

As shown in Table 4, the strong performance of the RM, CR, and CMR contrarian portfolios is obtained in the ETF universe. In particular, the CR strategy is the best performer among all the other contrarian strategies and is the only alternative strategy that outperforms the benchmark portfolio. The portfolio with the weekly performance of 0.094% and the volatility of 1.648% is not only greater but also less volatile than the cumulative return portfolio. The other recovery portfolios such as the CMR and RM strategies show good performance but the fluctuations of the weekly returns are larger than the traditional contrarian portfolio. Although the performance of the R strategy is not the best result, its standard deviation is at the lowest level, 1.217%.

The outperformance of the CR portfolio is based on the strong reversal in its ranking groups. The similar size of the reversion is achieved by every loser group in the alternative measures. In particular, the loser basket in the CR portfolio exhibits the strongest turn-around of 0.127%. Additionally, the volatility is the second lowest one among all the alternative ranking rules. Its strong mean-reversion is not limited to the loser group. The average weekly return of the CR winner is 0.034%, the poorest performance among all the short baskets including the benchmark. Moreover, the standard deviation of the performance is at one of the highest levels. The combination of the poorer performance and larger volatility in the CR short position makes the entire portfolio more likely to get profits.

According to Table 4, taking less risk leads to the outperformance of the CR strategy. The 95% VaR, CVaR, maximum drawdown of the strategy are 0.450%, 0.575%, and 20.46%, the second lowest VaR, CVaR, and maximum drawdown levels among the alternative portfolios. The CR portfolio also exhibit lower CVaR and maximum drawdown levels and the comparable size of VaR with the traditional contrarian portfolio. An interesting caveat is that the recovery portfolio exhibits the best risk profiles in every risk measures. Its 95% VaR, CVaR, and maximum drawdown are 0.340%, 0.443%, and 17.91% that are much lower than the risk measures of the traditional mean-reversion strategy. Meanwhile, the poorer risk measures are obtained by the other portfolios of which the construction rules are associated with the maximum drawdown.

Similar to the entire portfolio level, the better risk management in each ranking basket is provided by considering the recovery measure in the stock selection rules. In particular, the recovery criterion has the best loser group both in performance and risk. All the risk measures of the recovery loser are lower than any other loser groups of the alternative strategies including the



benchmark strategy. Moreover, the largest Shape ratio among the loser baskets is achieved by the loser in the recovery criterion. Opposite to the loser basket, the winner group in the recovery portfolio exhibits the worst risk measures and Sharpe ratio. Since the winner basket in the contrarian strategy is actually going short, the risky assets are helpful to gain the profit for the overall portfolio.

#### *4.2.2. Monthly results*

The alternative momentum portfolios constructed by the maximum drawdown related criteria outperform the cumulative momentum strategy in the SPDR U.S. sector ETFs universe. According to the summary statistics given in Table 5, the monthly performance of 0.172% under the standard deviation of 3.565% is achieved by the CMR strategy, the best performer among all criteria while the traditional momentum strategy generates monthly 0.117% under the volatility of 3.552%. The portfolio return is increased by almost 50% and the standard deviation is changed less than 1%. The RM and CM strategies with monthly returns of 0.138% and 0.121% are also followed by the C strategy. The both strategies are also less volatile than the cumulative return momentum strategy. The performance by the R and CR strategies are not only as good as the C strategy but also less volatile.

Regardless of criterion, the outperformance of the alternative portfolios is based on the strong momentum in each ranking basket. The winner and loser groups in the alternative portfolios consistently perform as well as the ranking groups of the traditional momentum strategy. In particular, the strongest momentum in the baskets is achieved by the CMR strategy: the long basket outperforms and the short basket underperforms that of the benchmark strategy. The winner and loser groups in the CM and RM portfolios are also under the strong trend-following phenomena. Other recovery related ranking rules also exhibit the same pattern. For example, the R and CR criteria also provide the strong momentum at the ranking group level.

In Table 5, the alternative portfolios are less riskier than the traditional momentum portfolio. First of all, the maximum drawdown of every strategy is lower or comparable with the benchmark case. Additionally, the 95% VaR and CVaR levels indicate that the recovery related selection rules are good at handling the severe losses. In particular, the RM portfolio takes low risk with achieving the better performance. The substantially less-riskier portfolios constructed by the R and CR criterion are also as good in performance as the trend-following strategy by cumulative return. Considering almost 50%-increased monthly return, the reward-risk ratio of the CMR portfolio is also improved because the risk measure of the portfolio is only slightly increased.

The alternative momentum strategies constructed by the maximum drawdown related measures are less riskier at the levels of the ranking baskets. The lower VaR and CVaR levels for the winner and the higher levels for the losers are found in the cases of the maximum drawdown strategies such as the M, MR, CM, and CMR strategies. These strategies also exhibit the smaller (larger) maximum drawdown for the winner (loser) group. Meanwhile, the opposite situation is observed in the ranking groups of the R and CR strategies. The

strategies show the larger (smaller) VaR and CVaR levels for the winner (loser) groups than that of the cumulative return strategy.

#### 4.3. U. S. equity market: S&P 500

##### 4.3.1. Weekly results

In Table 6, the alternative weekly contrarian portfolios constructed by the M, R, and CR criteria outperform the traditional contrarian portfolio. In particular, the recovery measure provides the best portfolio both in performance and volatility. The weekly return of 0.045% under the weekly standard deviation of 1.894% is achieved and both numbers are significantly improved with respect to the benchmark case. The CR strategy is also followed by the cumulative return mean-reversion strategy and its volatility level is one of the smallest ones. Although the maximum drawdown portfolio exhibits the second best average return, its performance is based on the largest volatility.

The alternative contrarian portfolios exhibit strong reversal at the level of each ranking basket. The loser groups in the R and CR portfolios achieve the largest weekly returns of 0.202% and 0.185%, respectively. In particular, the smallest standard deviation of 2.944% among the losers is achieved by the recovery loser although its weekly return is larger than the losers in any other portfolios including the benchmark loser group. While the winners in the alternative criteria show as consistent performance as the traditional contrarian winner basket, the winner group in maximum drawdown features the weakest weekly performance of 0.094% which is desirable to the short position. Moreover, the return fluctuation is also the smallest volatility among the winner baskets.

The recovery associated portfolios are less riskier than the traditional reversal portfolio according to the risk measures in Table 6. With the Shape ratio, every alternative strategies exhibit larger Sharpe ratios than the benchmark contrarian strategy. Additionally, the R, RM, CMR, and CR portfolios are less riskier in the 95% VaR and CVaR. Moreover, only the R and CR portfolios feature lower maximum drawdowns than the cumulative return strategy and the maximum drawdown of the R portfolios is at the lowest level and 50% decreased. More interesting finding is that the lowest level of the risk is achieved by the risk measures of the recovery portfolio. Meanwhile, the portfolios related to the maximum drawdown are exposed to the more risks. In particular, the risk measures of the M portfolio are at the worst level.

In each ranking basket, the recovery based portfolio is also more compatible with the risk profile of the contrarian strategy. Its loser basket exhibits the lowest risk measures such as 95% VaR, CVaR, and maximum drawdown. For example, the R and CR portfolios achieve the lowest 95% VaRs, CVaRs, maximum drawdowns in the loser groups, i.e. long positions. Additionally, the Sharpe ratio of the long position in the recovery portfolio is significantly larger than other portfolios including the benchmark portfolio and the CR criterion provides the second largest Sharpe ratio for the loser group. Meanwhile, the risk exposure of the winner in the recovery and CR measures is at the most

dangerous degree and worse than those of the benchmark winner. The VaR, CVaR, and maximum drawdown of the recovery portfolio hit the worst levels.

#### *4.3.2. Monthly results*

The maximum drawdown related momentum portfolios exhibit the better performance in the S&P 500 universe. The summary statistics in Table 7 show that the monthly return of 0.185% and the standard deviation of 6.240% are achieved by the CM strategy, the best performer among all the alternative strategies while the monthly return of 0.135% and the standard deviation of 5.869% are obtained by the traditional momentum strategy. The portfolios by other maximum drawdown based rules such as the CMR, M, and RM strategies are followed by the benchmark strategy in performance measure. These three portfolios generate monthly 0.179%, 0.160%, and 0.152%, respectively. Meanwhile, the recovery portfolios such as the R and CR criteria show poorer performance with smaller standard deviations. For example, the CR strategy slightly underperforms the original strategy by 10% and its volatility is also decreased by 10%.

The outperformance of the maximum drawdown momentum strategies is achieved by the poorer performance in the loser groups. Most loser groups of the alternative strategies underperform that of the momentum strategy. Except for the R-strategy, the short baskets of the composite ranking criteria provide 0.240%–0.378% while the cumulative return loser group obtains monthly 0.386%. When the baskets are in short-selling, the underperformance generates the profit for the long/short portfolios. The returns of the alternative long baskets are more consistent regardless of criterion. The performance of the winners is slightly worse than 0.521% by the momentum winner group but in the narrow range of 0.482%–0.520% except for the M-strategy which earns monthly 0.400%. Additionally, the winners in maximum drawdown related measures are less volatile than the recovery or cumulative return winners.

The outperformance of the maximum drawdown momentum strategies is achieved by taking low downside risk. According to the risk measures given in Table 7, the alternative strategies except for the M and CM portfolios tend to exhibit lower 95% VaR and CVaR measures. Even with the CM criterion, the performance of the portfolio is almost 50% improved and the risk measures are only 10% increased. In addition to that, the Sharpe ratios of the maximum drawdown strategies are greater than those of the recovery strategies and cumulative return based strategy. Additionally, the lower maximum drawdown is another characteristic of the maximum drawdown portfolios.

The risk measures of each ranking group support the outperformance of the maximum drawdown momentum strategies. The lower (higher) 95% VaR, CVaR, and maximum drawdown levels for winner (loser) groups are achieved by the maximum drawdown related stock selection rules. Its long position is less riskier than that of the momentum strategy while the opposite position is under the greater risk of losing money. This opposite behavior enables the portfolios profitable. Additionally, the higher Sharpe ratios are obtained by these strategies. Meanwhile, the recovery related strategies such as the R and CR

strategies exhibit the higher (lower) 95% VaR, CVaR, and maximum drawdown for the winner (loser) groups.

#### 4.4. Overall results

Regardless of asset class and market, the alternative portfolios constructed by the maximum drawdown and consecutive recovery achieve the better performance than the original momentum and contrarian strategies. In particular, employing the composite ranking rules are superior to using the only cumulative return, maximum drawdown, and recovery measures.

In weekly scale, the contrarian portfolios constructed by the recovery measures exhibit the outperformance over the traditional contrarian strategy. The R, CR, and CMR criteria are the best stock selection rules for the weekly contrarian strategy in any markets. The high performance and low volatility are featured by the portfolios. The historical cumulative returns of these portfolios are found in Figure 1.

For momentum portfolio construction, the maximum drawdown related measures are the best stock selection rules. The CM criterion provides the portfolios performing well in three different markets. The CMR and RM selection rules also predict future winners and losers well. Additionally, the volatility levels of the portfolio returns are relatively lower when the overall performance is considered. The cumulative returns of these portfolios are also given in Figure 2.

It is noteworthy that the price components related to the past and future directions expected by the momentum and reversal are important factors for portfolio construction in any time scale. For momentum, the maximal drawdown should be minimized for the winner but maximized for the loser because the winner is expected to outperform the loser. Meanwhile, the recovery for short-term contrarian should be smaller for losers. If the recovery is too large for the losers, it is considered that the asset already spent the fuel for the reversion and it is hard to exhibit the reversal.

The performance of the alternative portfolios is not the price of taking more risk. The alternative portfolios are less riskier in the better risk profiles such as VaR, CVaR, and maximum drawdown. It is also interesting that the risk measures of each ranking group are also well-matched to the purpose of portfolios construction: The winners (losers) groups are less (more) riskier in monthly scale. The ranking groups of the weekly contrarian strategy exhibit the opposite characteristics.

## 5. Factor analysis

As shown in the previous section, the maximum drawdown and consecutive recovery provide the useful stock selection rules for more profitable portfolios with low risk. The factor analysis with the Fama-French three-factors [5] also tests the outperformance of the alternative strategies. We focus on the S&P 500 universe.

### 5.1. Weekly

In Table 8, the intercepts and factor exposures of alternative contrarian strategies are given. All Fama-French three-factor alphas are negative except for the recovery portfolio. The positive and statistically significant alpha is achieved only by the recovery strategy. The R and CR portfolios exhibit greater alpha than the three-factor alpha of the traditional contrarian strategy. The intercepts for all other contrarian strategies are negative and smaller than the benchmark alpha.

The factor exposure of the recovery portfolio is unique. The R portfolio exhibits negative exposures to all the Fama-French three factors. Additionally, the negative exposures are all statistically significant. The CR and C portfolios show weak dependence on the market and value factors and negative exposure on the size factor. The  $R^2$  values of the C, CR, and CMR portfolios are relatively smaller.

The performance of the winner and loser baskets is explicable by the Fama-French three-factor model with high  $R^2$  values. Most of the factor exposures are positive and statistically significant. Meanwhile, the intercepts for the ranking baskets are negative and not statistically significant in most cases. The loser groups of the M and RM portfolios exhibit statistically significant alphas.

### 5.2. Monthly

The intercepts and factor loadings of the alternative momentum strategies are given in Table 9. All the intercepts of the regression model are positive except for the recovery strategy. Additionally, most of the portfolios outperform the cumulative return strategy if no factor exposure is given.

Different factor structures by the types of the stock selection rules are found. The first type of the ranking rules are the selection rules associated with the maximum drawdown. The alphas of the maximum drawdown related portfolios are greater than other strategies including the traditional momentum. In particular, the positive and statistically significant intercept is achieved only by the M strategy. Additionally, the larger portions of the returns by the maximum drawdown strategies are explained by the Fama-French three-factor model with higher  $R^2$ . The strategies are much exposed to the market factor and the value factor. The portfolio returns are negatively correlated with the size factor.

Contrary to the maximum drawdown based portfolios, the recovery portfolios such as the R and CR portfolios have the smaller intercepts than other strategies. In particular, the negative intercept is obtained by the R portfolio. The returns of these strategies are weakly dependent with the market and value factors but exhibit the positive exposures on the size factor than the drawdown portfolios. The  $R^2$  values are relatively lower.

The winner and loser baskets in each portfolio are well-explained by the Fama-French three-factor model with high  $R^2$  values. The differences in intercept and factor exposure with respect to the ranking criterion are originated from the characteristics in factor structure of each basket. The winner basket of the recovery momentum strategy not only has the a smaller intercept but also

exhibits more exposures on all the three factors than the loser basket. Meanwhile, the maximum drawdown portfolios are opposite: the higher alpha, less exposures to the Fama-French factors.

## 6. Conclusion

In this paper, we test the monthly momentum and weekly contrarian strategies with the alternative stock selection rules originating from maximum drawdown and consecutive recovery. The selection rules include not only the maximum drawdown and successive recovery but also the composite indices of them. The alternative portfolios are implemented in U.S. and South Korea equity markets.

In every markets, the performance of the alternative strategies is superior to the benchmark strategies. Additionally, the best portfolios are related to the construction rules that are related to the past and future directions expected by momentum and reversal. In weekly scale, the recovery related measures provide the better contrarian portfolios in the markets, i.e. smaller recovery expects more reversal. The R, CR, and CMR portfolios show the outperformance.

In monthly scale, the maximum drawdown associated strategies outperform the traditional momentum strategy, i.e. smaller maximum drawdown gives stronger momentum. The CM strategy is the overall best performer in every market. The CMR and CM portfolios are as good as the CM strategy.

The risk measures for the portfolios indicate that the portfolios are less riskier than the benchmark strategy. The portfolios tend to exhibit the lower VaR, CVaR, and maximum drawdown in the markets. The similar pattern is also observed at the levels of each long/short basket.

The factor analysis also shows that the unique pattern by the stock selection rules exists. In weekly, the intercept of the recovery portfolio is the largest one. The maximum drawdown portfolios have the higher intercept and larger exposures to the market and value factors than the traditional momentum strategy.

In future, the stock selection criteria based on the maximum drawdown and recovery will be tested in shorter time scales such daily and intraday frequencies. It will be useful to test the performance and risk of the alternative portfolios in various equity markets.

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## Reference

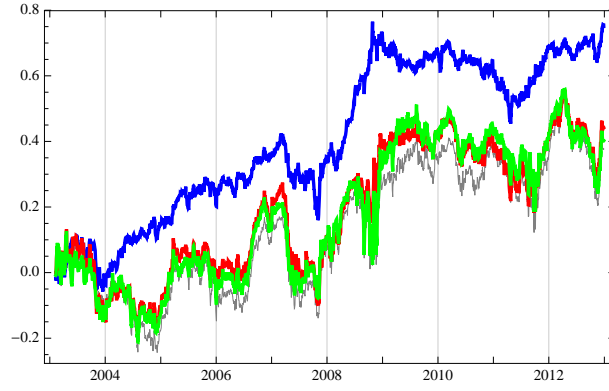
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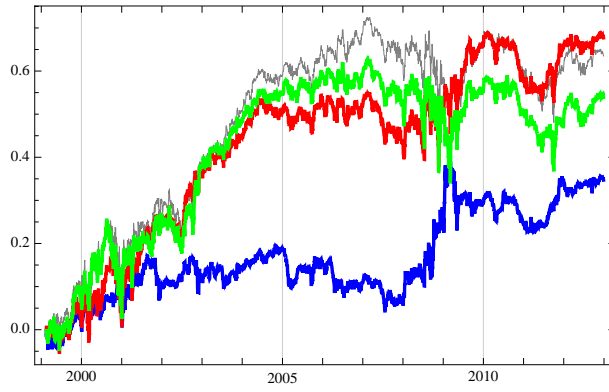
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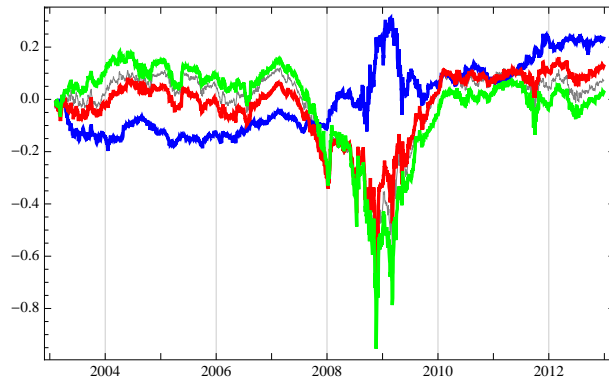




(a) South Korea KOSPI 200

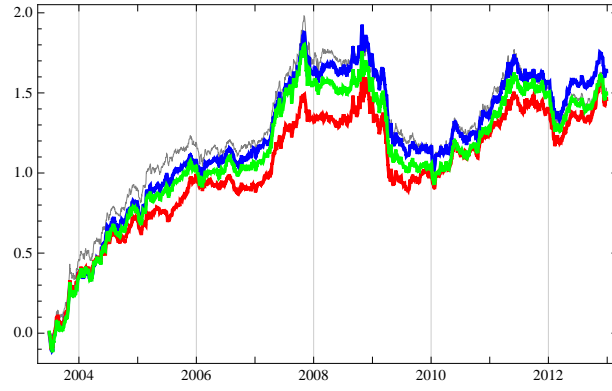


(b) U.S. sector ETF

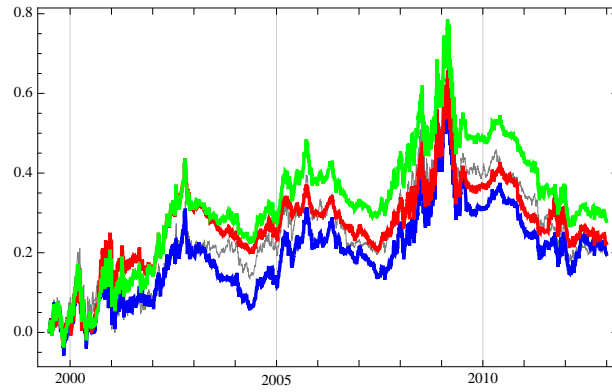


(c) U.S. S&P 500

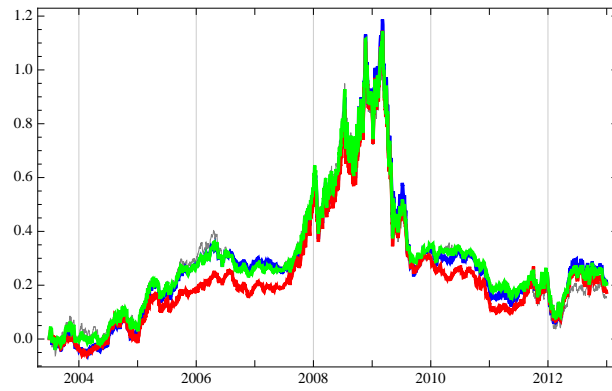
Figure 1: Cumulative returns for the traditional contrarian (gray), R (blue), CR (red), and CMR (green).



(a) South Korea KOSPI 200



(b) U.S. sector ETF



(c) U.S. S&P 500

Figure 2: Cumulative returns for the traditional momentum (gray), CM (blue), RM (red), and CMR (green).

Table 2: Summary statistics and risk measures of weekly 6/6 contrarian portfolios in South Korea KOSPI 200

Criterion	Portfolio	Summary statistics				Risk measures				
		Mean	Std. Dev.	Skewness	Kurtosis	Final Wealth	Sharpe	VaR <sub>95%</sub>	CVaR <sub>95%</sub>	MDD
Cumulative return	Winner (W)	0.1961	3.8032	-1.2946	6.7809	1.0119	0.0685	1.7519	2.5310	67.27
	Loser (L)	0.2692	4.3576	-1.1792	7.6903	1.3889	0.0813	1.6808	2.5153	63.00
	L – W	0.0731	2.8417	0.1864	1.8644	0.3770	0.0148	1.6864	2.4245	33.66
MDD	Winner (W)	0.2583	2.5125	-1.4858	7.4210	1.3330	0.0842	1.1302	1.6413	50.11
	Loser (L)	0.2574	4.7328	-1.1544	7.0878	1.3281	0.0681	1.9362	2.7975	67.43
	L – W	-0.0010	3.1694	-0.2546	2.7173	-0.0049	0.0140	1.7974	2.5476	60.08
Recovery	Winner (W)	0.1688	4.0728	-1.5786	9.1786	0.8712	0.0603	1.6462	2.2375	72.17
	Loser (L)	0.3143	3.3376	-1.4649	9.7503	1.6220	0.1003	1.2523	1.8700	51.78
	L – W	0.1455	1.7567	0.0996	1.8461	0.7508	0.0465	1.1494	1.3907	30.09
Recovery–MDD	Winner (W)	0.2279	3.4532	-1.5951	8.4947	1.1762	0.0753	1.5765	2.1820	65.22
	Loser (L)	0.2575	4.5200	-1.0493	6.8847	1.3286	0.0730	1.7822	2.6200	63.92
	L – W	0.0295	2.7489	0.3269	2.2130	0.1524	0.0131	1.6210	2.3542	36.66
Cumulative–MDD	Winner (W)	0.2258	3.4946	-1.2486	5.8310	1.1654	0.0737	1.6513	2.4019	61.34
	Loser (L)	0.2594	4.5592	-1.1455	7.4612	1.3384	0.0780	1.8532	2.7334	64.35
	L – W	0.0335	3.0442	0.1036	2.4027	0.1730	0.0165	1.8081	2.6182	41.05
Cumulative+Rec.	Winner (W)	0.1551	3.9277	-1.4040	7.7612	0.8003	0.0611	1.7428	2.4508	70.98
	Loser (L)	0.2408	4.2109	-1.1877	8.4200	1.2424	0.0808	1.6678	2.4696	63.16
	L – W	0.0857	2.6649	0.3887	1.4694	0.4421	0.0163	1.6105	2.2866	33.30
Cumulative–MDD+Rec.	Winner (W)	0.1829	3.6266	-1.3528	6.8595	0.9439	0.0662	1.6819	2.3703	66.13
	Loser (L)	0.2609	4.4422	-1.1052	7.4757	1.3461	0.0778	1.7475	2.5888	63.42
	L – W	0.0779	2.8645	0.2827	2.0772	0.4022	0.0165	1.7426	2.5012	33.34

Table 3: Summary statistics and risk measures of monthly 6/6 momentum portfolios in South Korea KOSPI 200

Criterion	Portfolio	Summary statistics				Risk measures				
		Mean	Std. Dev.	Skewness	Kurtosis	Final Wealth	Sharpe	VaR <sub>95%</sub>	CVaR <sub>95%</sub>	MDD
Cumulative return	Winner (W)	1.6292	8.7334	-0.4543	2.2045	1.8573	0.0775	1.7825	2.6373	64.48
	Loser (L)	0.2987	8.9425	-0.8357	5.5529	0.3405	0.0641	1.9006	2.6312	65.46
	W – L	1.3305	6.8258	0.0217	0.6760	1.5167	0.0545	2.5163	3.2597	59.87
MDD	Winner (W)	1.3075	5.5705	-0.5793	3.5011	1.4905	0.0885	1.1644	1.6563	46.13
	Loser (L)	0.2841	9.5852	-0.8019	4.3932	0.3239	0.0591	2.0981	2.8616	67.36
	W – L	1.0234	6.5769	-0.3515	1.0627	1.1667	0.0322	2.2287	2.7281	54.58
Recovery	Winner (W)	1.3299	8.7707	-0.7226	3.1472	1.5161	0.0818	1.8927	2.8033	69.11
	Loser (L)	0.9559	6.7652	-1.3312	6.0955	1.0898	0.0936	1.2107	1.7995	55.58
	W – L	0.3740	4.0823	0.9101	2.2150	0.4264	0.0127	1.6553	2.3164	37.97
Recovery–MDD	Winner (W)	1.5416	7.5704	-0.2469	1.5551	1.7574	0.0828	1.7765	2.6339	58.39
	Loser (L)	0.2613	9.3531	-0.7718	5.4615	0.2978	0.0613	2.0245	2.8005	67.25
	W – L	1.2803	6.2406	-0.3327	1.5967	1.4596	0.0569	2.5490	3.2939	52.06
Cumulative–MDD	Winner (W)	1.7005	8.0623	-0.3032	1.7154	1.9386	0.0785	1.6763	2.4660	59.37
	Loser (L)	0.2676	9.1117	-0.8241	5.4601	0.3051	0.0635	1.9590	2.6871	66.38
	W – L	1.4330	7.0357	-0.1969	0.5758	1.6336	0.0611	2.4930	3.1834	59.16
Cumulative+Rec.	Winner (W)	1.5449	8.8493	-0.5423	2.4918	1.7611	0.0778	1.8826	2.7816	67.88
	Loser (L)	0.4421	8.6716	-0.8298	6.2348	0.5040	0.0643	1.7340	2.4558	63.74
	W – L	1.1028	6.5956	0.2097	0.9879	1.2571	0.0404	2.3883	3.1240	62.37
Cumulative–MDD+Rec.	Winner (W)	1.5557	8.2241	-0.3319	1.7862	1.7735	0.0754	1.8104	2.6763	62.70
	Loser (L)	0.2451	9.1274	-0.8155	5.5803	0.2794	0.0625	1.9074	2.6450	66.39
	W – L	1.3106	6.7290	-0.2114	0.7663	1.4941	0.0575	2.5282	3.2651	58.32

Table 4: Summary statistics and risk measures of weekly 6/6 contrarian portfolios in U.S. sector ETF

Criterion	Portfolio	Summary statistics				Risk measures				
		Mean	Std. Dev.	Skewness	Kurtosis	Final Wealth	Sharpe	VaR <sub>95%</sub>	CVaR <sub>95%</sub>	MDD
Cumulative return	Winner (W)	0.0397	2.5424	-1.0070	5.6347	0.2876	0.0477	1.1783	1.4955	53.08
	Loser (L)	0.1274	2.9360	-0.4862	7.3610	0.9226	0.0408	1.2427	1.5333	60.12
	L – W	0.0877	1.7279	0.6594	7.4927	0.6350	0.0001	0.4469	0.6055	29.74
MDD	Winner (W)	0.0615	2.1450	-1.2742	7.7993	0.4454	0.0529	1.0917	1.4038	44.84
	Loser (L)	0.1116	3.3237	-0.3631	5.7091	0.8083	0.0441	1.3652	1.7236	63.96
	L – W	0.0501	2.1195	0.3290	5.5900	0.3629	0.0210	0.5570	0.7526	49.03
Recovery	Winner (W)	0.0654	2.8563	-0.8552	6.0406	0.4735	0.0460	1.1853	1.5648	61.57
	Loser (L)	0.1133	2.5224	-0.6937	6.5736	0.8206	0.0537	1.2192	1.4816	46.81
	L – W	0.0479	1.2174	0.5730	3.7388	0.3470	0.0000	0.3403	0.4426	17.91
Recovery–MDD	Winner (W)	0.0467	2.3858	-1.0909	6.1818	0.3384	0.0511	1.1193	1.4491	52.07
	Loser (L)	0.1158	3.1071	-0.3805	6.5959	0.8382	0.0408	1.2903	1.5781	60.78
	L – W	0.0690	1.7563	0.7227	9.7128	0.4998	0.0000	0.4724	0.6073	33.84
Cumulative–MDD	Winner (W)	0.0537	2.3661	-1.0646	5.4095	0.3891	0.0506	1.1356	1.4503	48.73
	Loser (L)	0.1197	3.1199	-0.4035	6.9313	0.8663	0.0399	1.2742	1.5995	63.77
	L – W	0.0659	1.8692	0.6222	8.1724	0.4772	0.0068	0.4846	0.6459	42.43
Cumulative+Rec.	Winner (W)	0.0335	2.6260	-1.0225	5.6197	0.2428	0.0458	1.1733	1.5236	57.61
	Loser (L)	0.1270	2.8685	-0.4025	7.3544	0.9198	0.0408	1.3345	1.6153	56.89
	L – W	0.0935	1.6477	0.7112	6.8603	0.6770	0.0000	0.4504	0.5750	20.46
Cumulative–MDD+Rec.	Winner (W)	0.0463	2.4735	-0.9579	5.0344	0.3353	0.0496	1.1432	1.4590	53.24
	Loser (L)	0.1208	3.0348	-0.3624	6.7464	0.8744	0.0398	1.3061	1.5975	61.50
	L – W	0.0745	1.7891	0.7205	8.0367	0.5392	0.0000	0.5092	0.6519	32.00

Table 5: Summary statistics and risk measures of monthly 6/6 momentum portfolios in U.S. sector ETF

Criterion	Portfolio	Summary statistics				Risk measures				
		Mean	Std. Dev.	Skewness	Kurtosis	Final Wealth	Sharpe	VaR <sub>95%</sub>	CVaR <sub>95%</sub>	MDD
Cumulative return	Winner (W)	0.3742	4.5444	-0.7738	1.3970	0.6062	0.0518	1.3639	1.7161	48.23
	Loser (L)	0.2568	5.3434	-0.6718	1.6714	0.4160	0.0373	1.4811	1.7675	65.48
	W – L	0.1174	3.5522	-0.1950	1.6853	0.1903	0.0001	0.5529	0.7246	39.55
MDD	Winner (W)	0.2820	3.6813	-0.8993	2.3732	0.4569	0.0540	1.2180	1.5566	44.57
	Loser (L)	0.1869	5.7772	-0.4749	0.9533	0.3027	0.0361	1.6286	1.9842	64.60
	W – L	0.0951	3.5423	-0.1730	1.7801	0.1541	-0.0025	0.7813	1.0325	38.14
Recovery	Winner (W)	0.3616	5.0347	-0.7006	1.7317	0.5859	0.0491	1.5282	1.9039	59.12
	Loser (L)	0.2463	4.3456	-0.6546	1.3965	0.3990	0.0452	1.3462	1.6252	49.28
	W – L	0.1154	2.7612	-0.2002	0.9125	0.1869	0.0001	0.3750	0.5204	29.21
Recovery–MDD	Winner (W)	0.3568	4.0697	-0.9282	1.9866	0.5780	0.0488	1.2738	1.6263	46.52
	Loser (L)	0.2191	5.4810	-0.5295	1.1879	0.3549	0.0371	1.4805	1.8016	63.39
	W – L	0.1377	3.2694	-0.4041	3.0940	0.2231	-0.0000	0.5050	0.6658	35.87
Cumulative–MDD	Winner (W)	0.3810	4.2173	-0.8257	1.6097	0.6172	0.0458	1.2515	1.6113	44.80
	Loser (L)	0.2599	5.4694	-0.5744	1.2093	0.4210	0.0322	1.5393	1.8406	63.52
	W – L	0.1211	3.4904	-0.3021	2.1704	0.1962	0.0000	0.6991	0.8904	37.85
Cumulative+Rec.	Winner (W)	0.4015	4.6474	-0.7771	1.4298	0.6504	0.0541	1.4251	1.8317	50.05
	Loser (L)	0.2911	5.0446	-0.5675	1.6271	0.4716	0.0420	1.3626	1.6324	61.33
	W – L	0.1104	3.2966	-0.3510	1.2258	0.1788	0.0001	0.3790	0.4868	36.23
Cumulative–MDD+Rec.	Winner (W)	0.4009	4.3287	-0.8553	1.5424	0.6495	0.0469	1.2709	1.6388	46.38
	Loser (L)	0.2286	5.4417	-0.5751	1.2593	0.3703	0.0331	1.5221	1.8123	64.15
	W – L	0.1724	3.5652	-0.3392	1.9933	0.2792	0.0000	0.6383	0.7834	40.65

Table 6: Summary statistics and risk measures of weekly 6/6 contrarian portfolios in U.S. S&amp;P 500

Criterion	Portfolio	Summary statistics				Risk measures				
		Mean	Std. Dev.	Skewness	Kurtosis	Final Wealth	Sharpe	VaR <sub>95%</sub>	CVaR <sub>95%</sub>	MDD
Cumulative return	Winner (W)	0.1545	3.4269	-0.8186	6.8648	0.7970	0.0560	1.3386	1.7016	63.77
	Loser (L)	0.1685	4.6130	-0.1908	11.7318	0.8693	0.0494	1.3727	1.7022	81.06
	L – W	0.0140	2.7235	0.5559	18.0504	0.0722	-0.0018	0.5749	0.7774	68.14
MDD	Winner (W)	0.0941	1.8080	-1.7153	14.3482	0.4858	0.0665	0.9660	1.2390	42.75
	Loser (L)	0.1330	5.4226	-0.0581	8.7693	0.6862	0.0367	1.5473	1.9427	84.81
	L – W	0.0388	4.2834	0.5514	11.5404	0.2004	0.0108	0.8726	1.1586	85.89
Recovery	Winner (W)	0.1571	4.2265	-0.5915	8.0259	0.8106	0.0485	1.4418	1.8567	72.18
	Loser (L)	0.2024	2.9440	-0.5202	9.3128	1.0442	0.0770	1.1436	1.4756	59.09
	L – W	0.0453	1.8942	-0.3874	14.1420	0.2336	0.0029	0.4783	0.6290	34.65
Recovery–MDD	Winner (W)	0.1418	2.8429	-1.1089	7.5609	0.7319	0.0609	1.2627	1.6121	57.66
	Loser (L)	0.1205	4.9787	-0.2042	10.1750	0.6216	0.0429	1.4418	1.8103	84.29
	L – W	-0.0214	3.1059	0.3535	21.3982	-0.1103	0.0074	0.5464	0.7585	77.06
Cumulative–MDD	Winner (W)	0.1329	2.8026	-0.9900	5.7244	0.6860	0.0617	1.2509	1.5900	57.59
	Loser (L)	0.1385	4.9616	-0.2106	10.4703	0.7146	0.0433	1.4433	1.8060	84.00
	L – W	0.0055	3.2731	0.5005	19.5205	0.0286	0.0044	0.6020	0.8273	78.42
Cumulative+Rec.	Winner (W)	0.1602	3.6578	-0.7068	7.0300	0.8264	0.0536	1.3591	1.7390	65.75
	Loser (L)	0.1848	4.3762	-0.0598	12.1970	0.9536	0.0517	1.3629	1.6812	78.68
	L – W	0.0247	2.5212	0.4148	15.3566	0.1272	-0.0009	0.5745	0.7780	60.46
Cumulative–MDD+Rec.	Winner (W)	0.1379	3.1150	-1.0011	6.9205	0.7116	0.0562	1.3127	1.6669	60.12
	Loser (L)	0.1432	4.7905	-0.1819	11.2766	0.7388	0.0463	1.4082	1.7604	82.92
	L – W	0.0053	2.9710	0.4719	21.3172	0.0272	0.0056	0.5547	0.7546	74.13

Table 7: Summary statistics and risk measures of monthly 6/6 momentum portfolios in U.S. S&amp;P 500

Criterion	Portfolio	Summary statistics				Risk measures				
		Mean	Std. Dev.	Skewness	Kurtosis	Final Wealth	Sharpe	VaR <sub>95%</sub>	CVaR <sub>95%</sub>	MDD
Cumulative return	Winner (W)	0.5207	5.4226	-0.8283	1.0570	0.5936	0.0548	1.6548	1.9514	56.70
	Loser (L)	0.3862	8.1115	0.0315	3.7771	0.4402	0.0369	1.8685	2.0034	80.28
	W – L	0.1345	5.8692	-1.5902	9.5354	0.1533	0.0060	1.1323	1.4689	65.05
MDD	Winner (W)	0.3996	2.9461	-1.6477	5.3286	0.4555	0.0659	1.1147	1.4830	42.61
	Loser (L)	0.2398	8.8190	0.0228	1.9067	0.2734	0.0315	2.0026	2.1785	81.31
	W – L	0.1597	7.1307	-0.8664	3.9332	0.1821	0.0008	1.5681	1.7568	69.40
Recovery	Winner (W)	0.5030	6.6957	-0.5231	1.4928	0.5735	0.0517	1.7725	2.0429	72.42
	Loser (L)	0.5907	4.9978	-1.1764	4.6055	0.6734	0.0679	1.3524	1.6042	58.84
	W – L	-0.0876	3.1151	-0.7435	2.6854	-0.0999	0.0167	0.5746	0.7087	41.29
Recovery–MDD	Winner (W)	0.4912	4.4369	-0.9406	1.4538	0.5600	0.0542	1.5068	1.8224	52.14
	Loser (L)	0.3391	8.5186	0.0410	2.7849	0.3865	0.0341	1.8999	2.0506	81.15
	W – L	0.1522	5.9310	-1.8047	10.2498	0.1735	0.0075	1.1213	1.3830	66.01
Cumulative–MDD	Winner (W)	0.4824	4.6982	-0.9008	1.3118	0.5499	0.0589	1.5884	1.8747	53.69
	Loser (L)	0.2976	8.5087	0.0268	2.7663	0.3393	0.0343	1.9262	2.0662	81.41
	W – L	0.1848	6.2404	-1.5782	8.4758	0.2106	0.0059	1.2391	1.5414	67.73
Cumulative+Rec.	Winner (W)	0.4980	5.6849	-0.7882	0.7682	0.5678	0.0573	1.7250	1.9887	60.49
	Loser (L)	0.3777	7.7708	-0.0968	4.5905	0.4306	0.0407	1.8039	1.9443	78.66
	W – L	0.1203	5.2923	-1.4184	8.9592	0.1372	0.0002	0.9499	1.2799	60.28
Cumulative–MDD+Rec.	Winner (W)	0.5196	4.9916	-0.8961	1.2364	0.5923	0.0539	1.6096	1.9175	55.17
	Loser (L)	0.3408	8.3077	0.0104	3.3067	0.3886	0.0363	1.8954	2.0390	81.05
	W – L	0.1787	5.9297	-1.7243	10.3269	0.2037	0.0078	1.1499	1.4681	65.58



Table 8: Fama-French regression of weekly 6/6 contrarian portfolios in U.S. S&P 500

Criterion	Portfolio	Factor loadings				$R^2$
		$\alpha(\%)$	$\beta_{MKT}$	$\beta_{SMB}$	$\beta_{HML}$	
Cumulative return	Winner (W)	-0.0494	1.1237**	0.2532**	0.2906**	0.8744
	Loser (L)	-0.0965	1.4406**	0.1721*	0.6591**	0.8445
	L – W	-0.0471	0.3169**	-0.0810	0.3685**	0.1602
MDD	Winner (W)	0.0047	0.6754**	-0.1448**	-0.1222**	0.8471
	Loser (L)	-0.1897*	1.5955**	0.3761**	1.0971**	0.8638
	L – W	-0.1945	0.9201**	0.5209**	1.2193**	0.6798
Recovery	Winner (W)	-0.0994	1.3435**	0.2755**	0.6570**	0.9080
	Loser (L)	0.0309	1.0689**	0.0088	0.1174**	0.9458
	L – W	0.1303*	-0.2746**	-0.2667**	-0.5396**	0.4502
Recovery–MDD	Winner (W)	-0.0222	0.9763**	0.1229**	0.1081**	0.8745
	Loser (L)	-0.1723*	1.5370**	0.2604**	0.8106**	0.8645
	L – W	-0.1500	0.5606**	0.1374	0.7025**	0.4339
Cumulative–MDD	Winner (W)	-0.0271	0.9579**	0.1506**	0.0442	0.8520
	Loser (L)	-0.1517	1.5166**	0.2565**	0.8286**	0.8554
	L – W	-0.1246	0.5586**	0.1059	0.7844**	0.4150
Cumulative+Rec.	Winner (W)	-0.0587	1.1904**	0.2685**	0.3697**	0.8814
	Loser (L)	-0.0650	1.3810**	0.1372	0.5804**	0.8428
	L – W	-0.0063	0.1906**	-0.1313	0.2108*	0.0643
Cumulative–MDD+Rec.	Winner (W)	-0.0445	1.0426**	0.2018**	0.1728**	0.8671
	Loser (L)	-0.1345	1.4811**	0.2159**	0.7355**	0.8492
	L – W	-0.0900	0.4386**	0.0141	0.5628**	0.2847
** 1% significance		* 5% significance				

Table 9: Fama-French regression of monthly 6/6 momentum portfolios in U.S. S&P 500

Criterion	Portfolio	Factor loadings				
		$\alpha(\%)$	$\beta_{MKT}$	$\beta_{SMB}$	$\beta_{HML}$	$R^2$
Cumulative return	Winner (W)	-0.0855	1.0061**	0.3656**	-0.0642	0.7869
	Loser (L)	-0.5270	1.5391**	0.1749	0.3457*	0.8026
	W – L	0.4415	-0.5330**	0.1906	-0.4099	0.2057
MDD	Winner (W)	0.1109	0.6204**	-0.1077	-0.0089	0.7824
	Loser (L)	-0.8071*	1.6119**	0.4258*	0.4787**	0.8300
	W – L	0.9180*	-0.9916**	-0.5334*	-0.4876**	0.6036
Recovery	Winner (W)	-0.3169	1.2997**	0.2715**	0.3641**	0.9033
	Loser (L)	0.0056	1.0678**	0.0955	0.0389	0.9299
	W – L	-0.3225	0.2319**	0.1760	0.3252**	0.2925
Recovery–MDD	Winner (W)	-0.0081	0.8703**	0.2145*	-0.0413	0.8274
	Loser (L)	-0.6613	1.5904**	0.3701*	0.3803**	0.8307
	W – L	0.6532	-0.7202**	-0.1556	-0.4217*	0.4112
Cumulative–MDD	Winner (W)	-0.0367	0.8847**	0.2958**	-0.0899	0.7880
	Loser (L)	-0.6901*	1.5843**	0.3056	0.4203**	0.8189
	W – L	0.6533	-0.6996**	-0.0098	-0.5102*	0.3475
Cumulative+Rec.	Winner (W)	-0.1586	1.0704**	0.3174**	0.0841	0.8193
	Loser (L)	-0.4931	1.4920**	0.1695	0.2650	0.8050
	W – L	0.3345	-0.4216**	0.1479	-0.1810	0.1296
Cumulative–MDD+Rec.	Winner (W)	-0.0355	0.9483**	0.2934**	-0.0714	0.7970
	Loser (L)	-0.6101	1.5711**	0.2503	0.3486*	0.8148
	W – L	0.5747	-0.6229**	0.0431	-0.4200*	0.2863
** 1% significance		* 5% significance				